Helium Recovery From Natural Gas

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Foreword

Since 1976, numerous projects have been initiated in Alberta by industry and by academic research institutions which are aimed at better utilization of Alberta's energy resources.

These research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the producing provinces.

Responsibility for applying and administering the fund rests with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities have focused on coal, energy conservation and renewable energy and conventional energy resources. Administration for the program is provided by staff within the Scientific and Engineering Services and Research Division of Alberta Energy.

In order to make research results available to industry and others who can use the information, highlights of studies are reported in a series of technology transfer booklets. For more information about other publications in the series, please refer to page six.

Helium Recovery From Natural Gas

Helium, the second lightest element after hydrogen, is a valued commodity in technologically advanced countries. What was once a single-purpose gas used only in lighter-than-air craft such as scientific and weather balloons, is now widely used because of its various properties.

Because its boiling point (-268.9°C) is the lowest of all substances, helium in the liquid state can provide the extremely low temperature (cryogenic) environments needed to freeze biological specimens in cancer research or produce superconductivity in certain materials. Helium can be used to provide the cryogenic conditions needed for superconductors used in plasma containment for fusion energy and magnetohydrodynamic energy systems.

Helium is also chemically inert. This property allows it to be used as a pressurizing gas in aerospace applications, as an inert environment for gas-shielded arc welding or to provide a controlled atmosphere in which semi-conductor crystals are grown.

Helium's inert characteristics, combined with high thermal conductivity, make it an excellent heat transfer medium for gas-cooled nuclear reactors without concerns about it becoming radioactive.

It is expected that demand for helium will continue to grow in such fields as electronics, space exploration, transportation and advanced energy systems but its supply from current sources is declining.

At one time helium was extracted from natural gas at a plant in Swift Current, Saskatchewan, but that facility, which was Canada's only domestic source of helium, closed in 1977 when the natural gas reserve became depleted. Since then, annual Canadian requirements of approximately 560 000 m^3 (20 million cu.ft.) have been met by importing helium from the United States. However, American supplies are also dwindling, leading to the conclusion that importing may become difficult, if not impossible, by the late 1980s.

Although helium could be extracted from the atmosphere, it is present in such low concentrations (five parts per million) that costs to extract it are prohibitive. Consequently, the only economically viable source for production of large quantities of helium has been helium-bearing natural gas, which typically contains 0.3 to 1 per cent helium in deposits that supply U.S. plants.

Currently in the United States, helium is extracted using a cryogenic process in which natural gas is cooled to a temperature low enough to liquefy all the less volatile constituents and leave a vapor fraction rich in helium. While the technology is proven, it involves high capital and energy costs.

An alternative process developed by the Alberta Research Council uses semi-permeable membranes to extract helium from natural gas at the lower concentrations typically found in Alberta, ranging from 0.01 to 1.5 per cent and averaging about 0.05 per cent. The process depends on the ability of helium to diffuse readily through a semi-permeable membrane because of its small molecular size and thus be selectively separated from other constituents of natural gas.

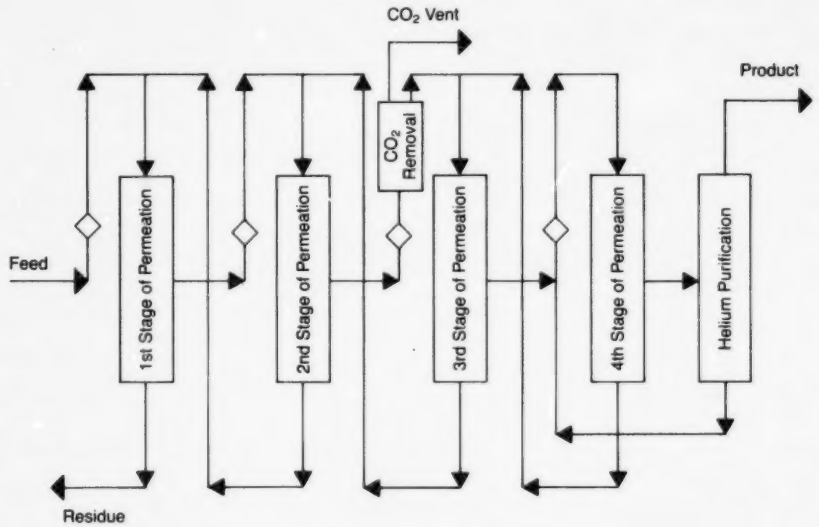
Because laboratory results suggested the process had commercial potential and might be less costly than cryogenic systems, Alberta Helium Limited was established in 1973 to pursue commercial development of the technology. From 1977 to 1982, this effort was supported by funding from A/CERRF.

Helium in Alberta

According to estimates prepared by Alberta's Energy Resources Conservation Board, helium present in proven reserves of Alberta natural gas amounts to 900 million m^3 (32 billion cu.ft.). Approximately 135 million m^3 (4.8 billion cu.ft.) are present in natural gas at concentrations of 0.1 per cent or greater, 190 million m^3 (6.8 billion cu. ft.) are at concentrations of 0.05 to 0.1 per cent and 575 million m^3 (20 billion cu. ft.) are contained in natural gas at lower concentrations. Because none of this helium is recovered today, it has been estimated that over 28 million m^3 (one billion cu.ft.) of helium are lost to the atmosphere each year from recovery and consumption of Alberta natural gas.

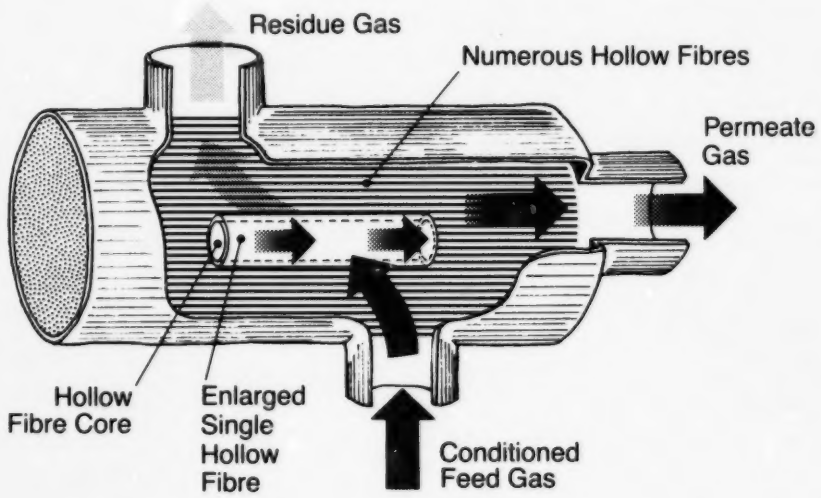
Gas deposits containing relatively rich concentrations (at least 0.1 per cent) are found in southern Alberta as well as near Fox Creek and Peace River.

Schematic of Alberta Helium Pilot Plant Process



(Source: *The Permeation Process for the Recovery of Helium from Natural Gas*. Alberta Helium Limited, January 1982)

Schematic Drawing of a Typical Membrane Module



(Source: International Permeation Inc., 1986)

Pilot Plant Studies

Using these concentrations as a guideline, Alberta Helium built a pilot plant at the McLeod River Compressor Station of Alberta Gas Trunk Line Company Limited to demonstrate the permeation process on a practical scale and generate design and cost data for a commercial plant. This included development of a mathematical model to predict the performance of the permeation technology.

The pilot plant was designed to handle 85 000 m^3 (three million standard cu. ft.) per day of natural gas, and to separate helium in four permeation stages.

The process uses commercially available hollow fibre, "water-wet" membranes that are normally used to purify water in desalination schemes. However, to successfully separate helium, the membranes must first be dried using a patented process to make them suitable for gas permeation. Typical hollow fibre modules used in the pilot plant contained up to 270 000 individual fibres.

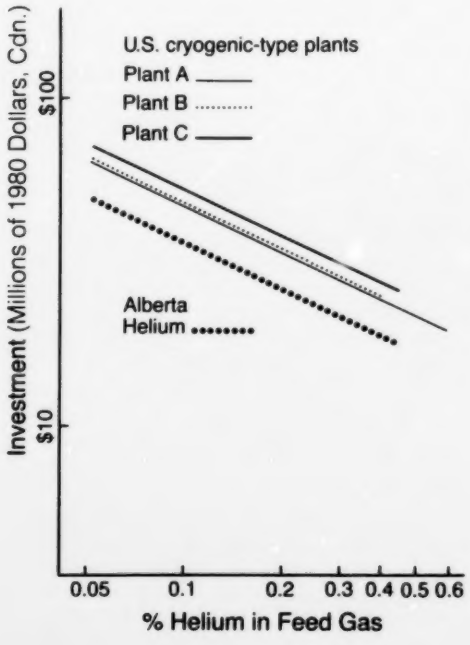
In the Alberta Helium process, natural gas at normal pipeline pressures is first filtered to remove scale, oil and other trace liquids, and then it is compressed and passed through the first permeation stage. Here, the helium concentration is increased from a low of 0.05 per cent to 0.6 to 1.4 per cent.

The helium-enriched gas is again compressed, followed by a second permeation separation which raises the helium concentration to 3.3 to 8.1 per cent. After another compression stage, followed by removal of carbon dioxide, the helium-containing gas undergoes two more permeation treatments, which raise the helium concentration to 72 to 90 per cent.

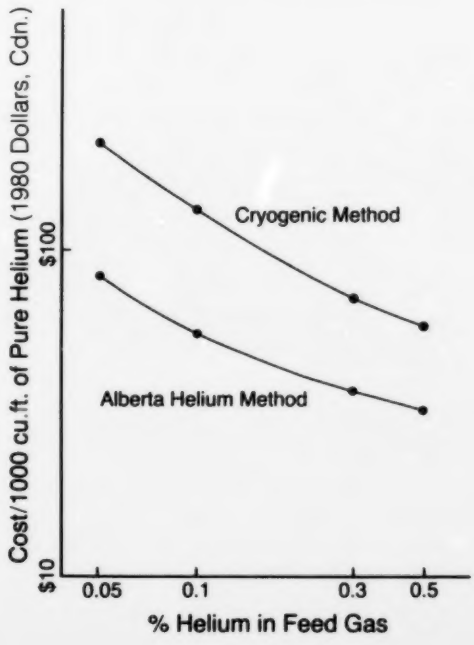
After on-site purification to remove hydrogen and moisture, a final product gas which is 99.997 per cent helium is formed, some of which is liquefied while the remainder is stored as a gas under pressure.

Unlike in cryogenic systems, in the permeation process the bulk of the input stream flows unaffected through the equipment. Because process work is performed only on the helium, the process requires only 40 per cent of the energy needed in conventional cryogenic plants.

Plant Investment



Direct Operating Costs – Permeation Versus Cryogenic Processes



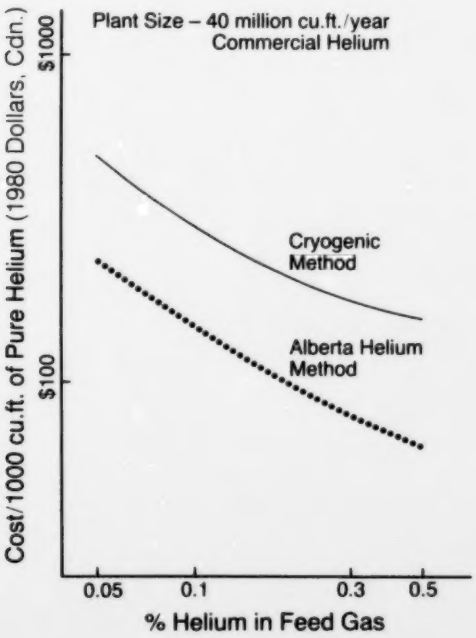
(Source: *The Permeation Process for the Recovery of Helium from Natural Gas*, Alberta Helium Limited, January 1982)

Commercial-Scale Design

In 1981, an engineering firm (Associated-Pullman Kellogg Ltd.) prepared a cost estimate of a preliminary design for a commercial scale plant. It would produce 700 000 m^3 (25 million cu.ft.) of gaseous helium and 425 000 m^3 (15 million cu.ft.) of liquid helium per year from feed gas containing either 0.05 per cent or 0.1 per cent helium.

On this basis, it was found that capital and annual operating costs for a plant recovering helium from 0.05 per cent feedstock would be $50 million and $2.8 million respectively, while for feed gas containing 0.1 per cent helium the respective costs were estimated to be $36 million and $2.7 million. Subsequent revisions to the design showed how the overall cost of the process could be lowered.

Total Recovery Costs
(at 15% rate of return)



Subsequent Developments

Since 1982, an overcapacity situation has prevailed in helium markets. This led Alberta Helium to postpone plans for commercial development of their permeation technology.

Meanwhile, another Calgary company, Delta Projects Inc., and several natural gas transmission companies, began research and development programs in membrane technology to separate carbon dioxide and hydrogen sulphide from sour natural gas. In 1985, Alberta Helium and Delta Projects decided to join forces and subsequently created International Permeation Inc., a Calgary-based firm which provides custom-designed gas separation systems. This service employs hollow fibre permeable membranes under varying conditions of pressure to selectively remove and recover such gases as carbon dioxide, hydrogen sulphide, hydrogen and helium.

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